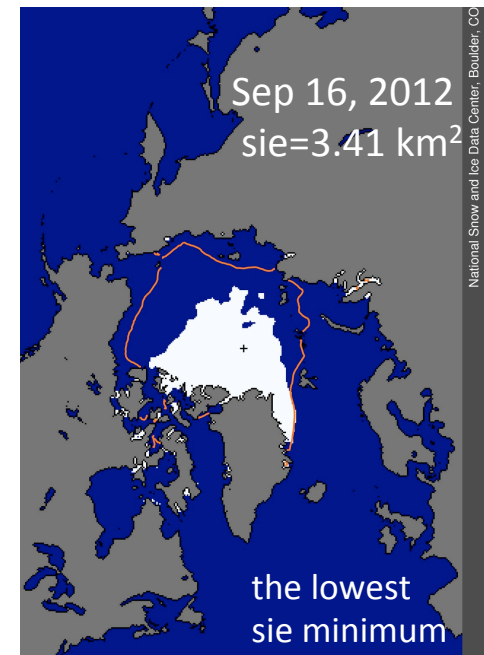
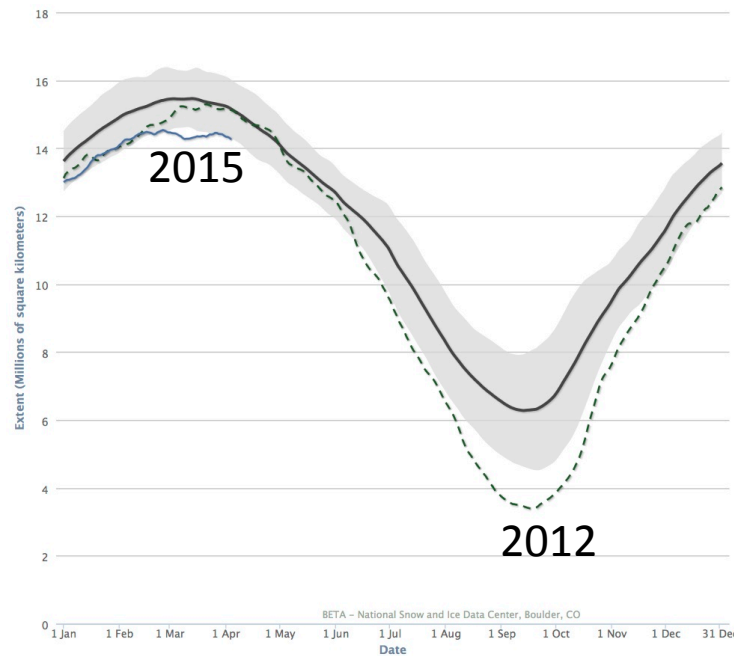
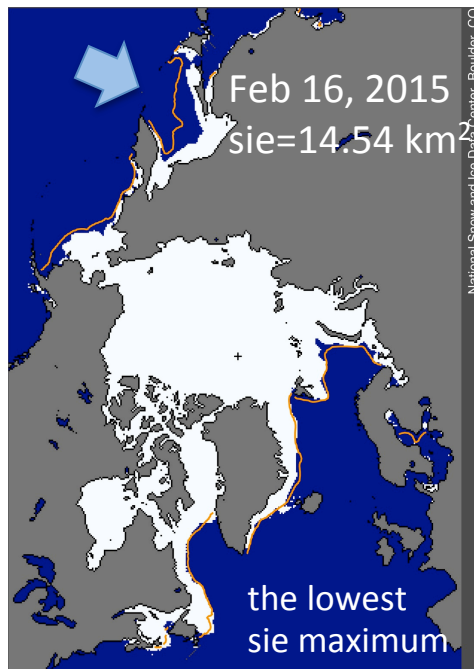


Elements of polar climate and changes in cryosphere

Neven S. Fučkar¹ (nevensf@gmail.com)

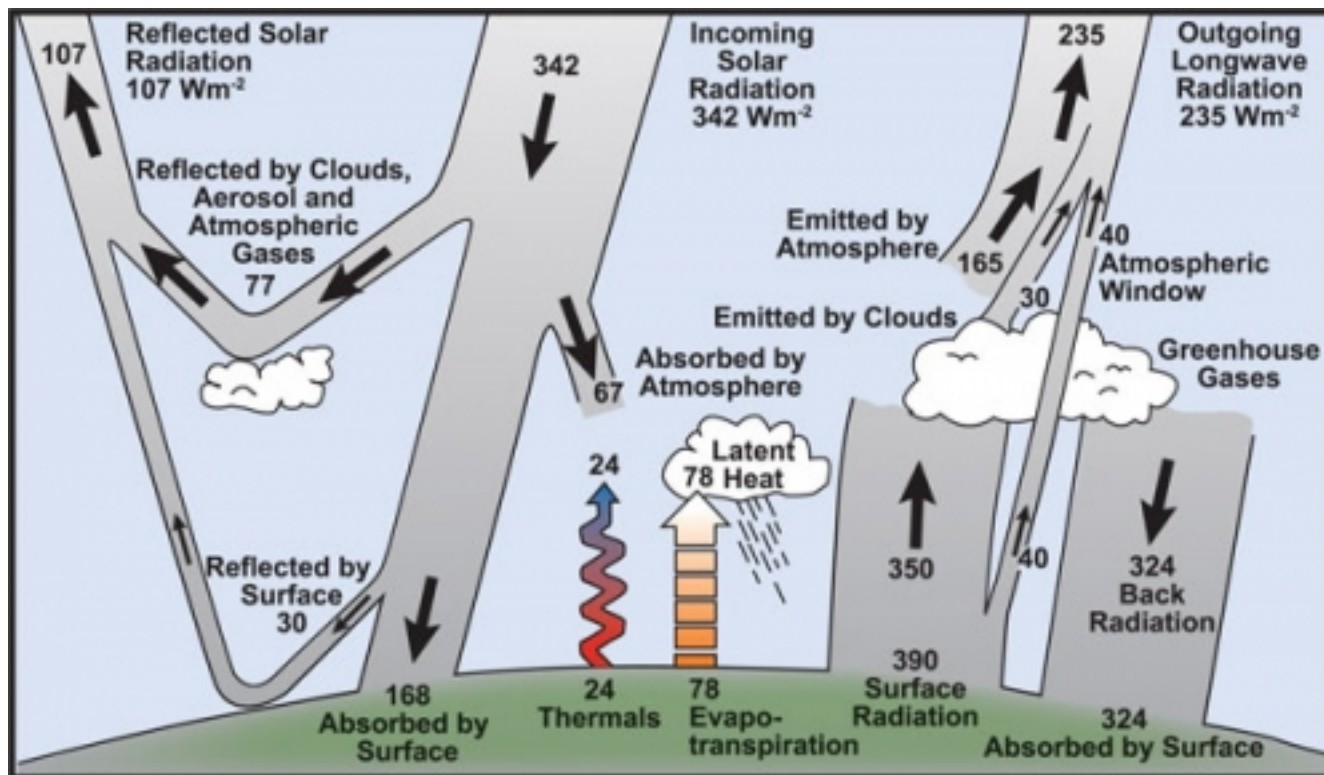
¹*Institut Català de Ciències del Clima (IC3), Barcelona, Spain*



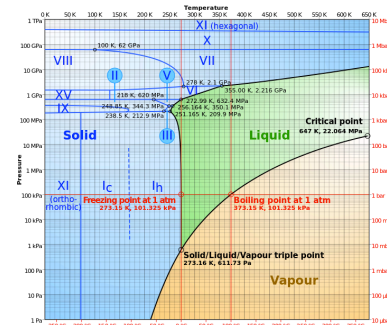
April 15, SC10/SSS0.16 The future of permafrost in a climate-changing world, EGU, Vienna, Austria, April 13-17, 2015



Global energy balance



The triple point of water is essential!

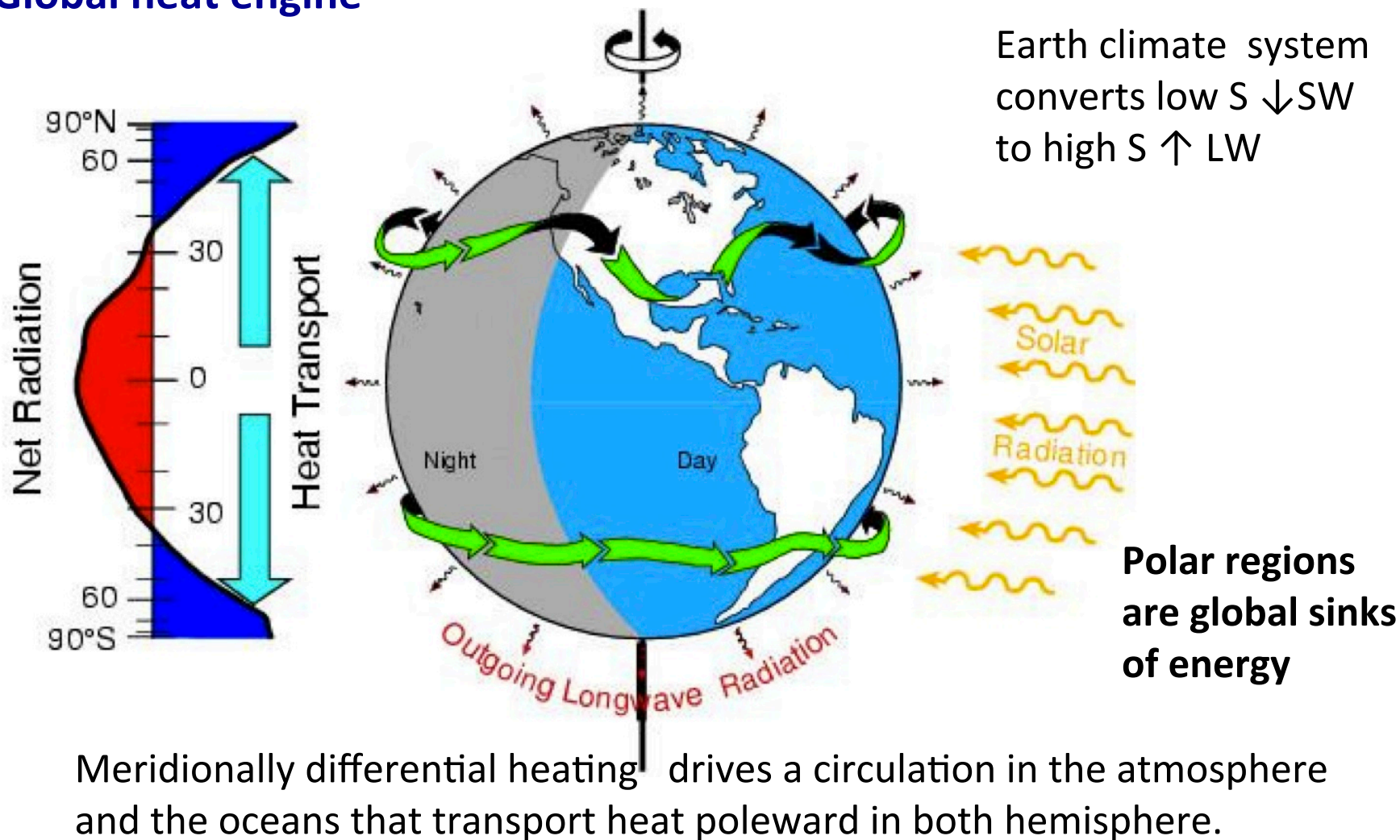


$$T_{tp} = 273.16 \text{ K} = 0.01^\circ \text{C}$$

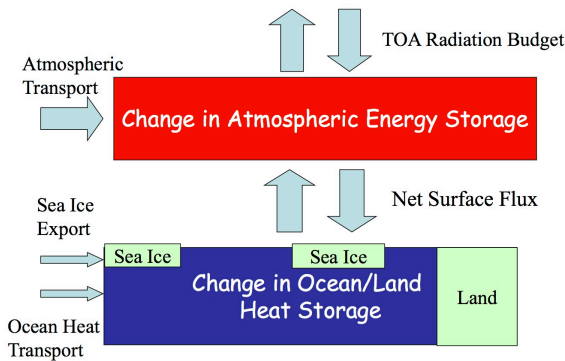
$$p_{tp} = 611.73 \text{ Pa} = 6.1173 \text{ mbar}$$

Atmosphere is radiatively heated at surface and cooled from free troposphere
Forms of water (oceans, clouds, **polar ice caps**, ...) dominate energy balance

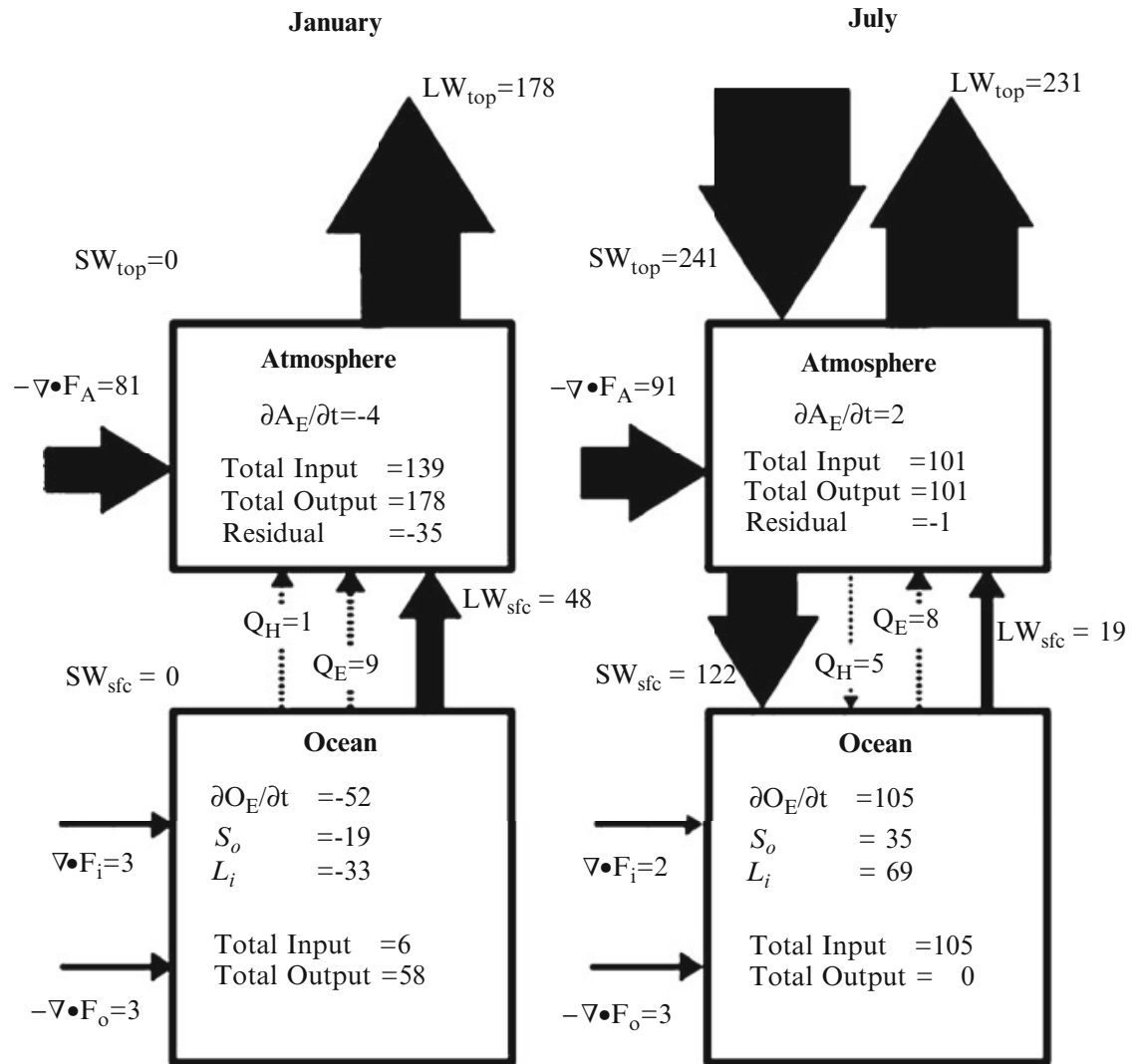
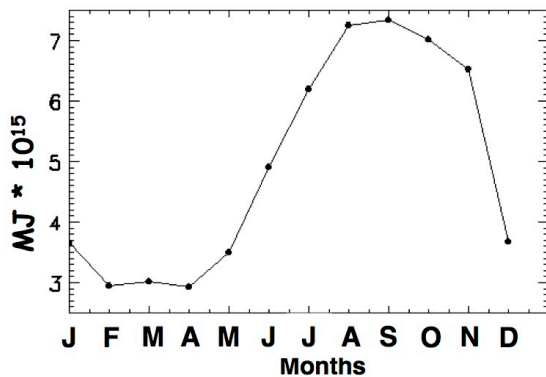
Global heat engine



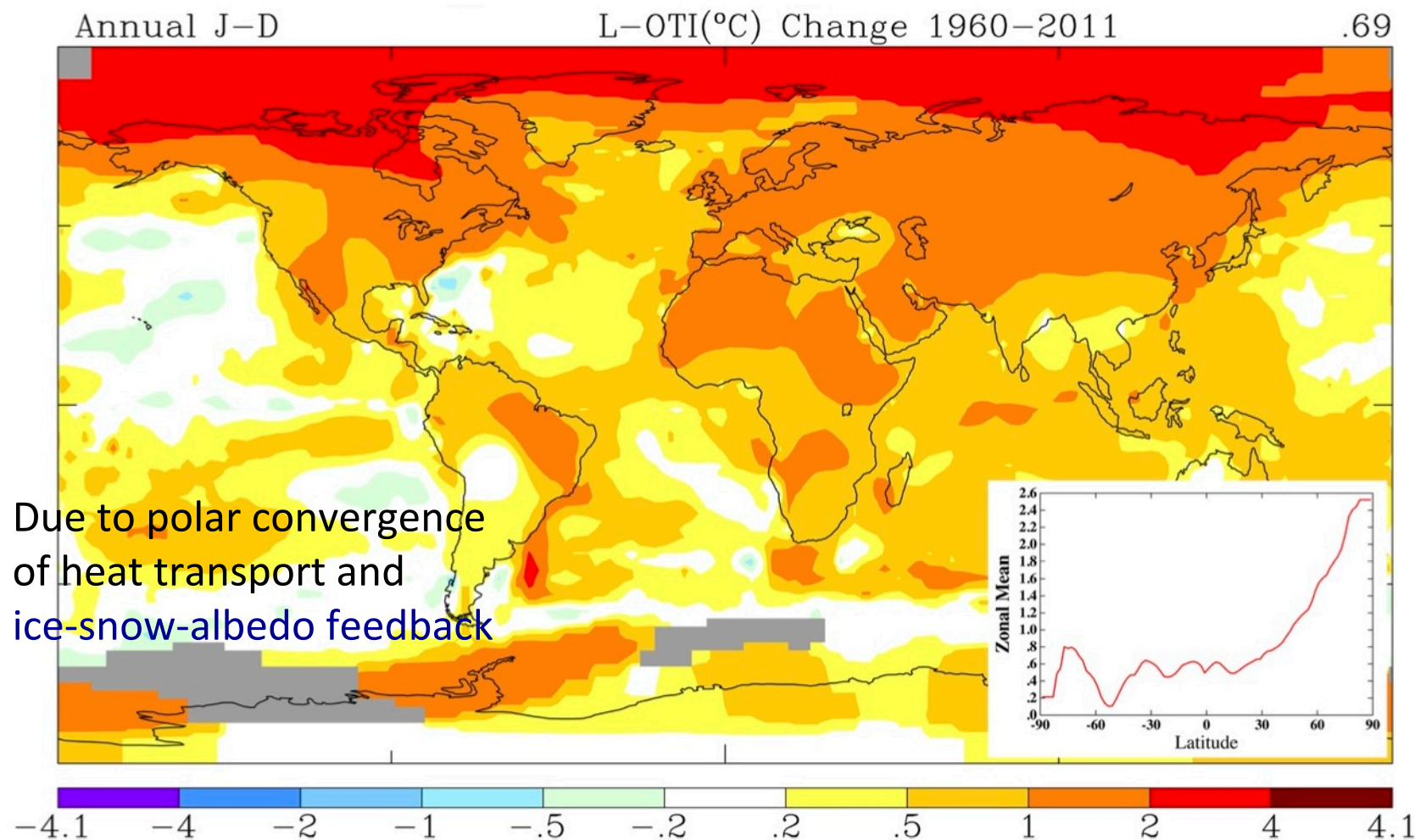
Arctic energy budget



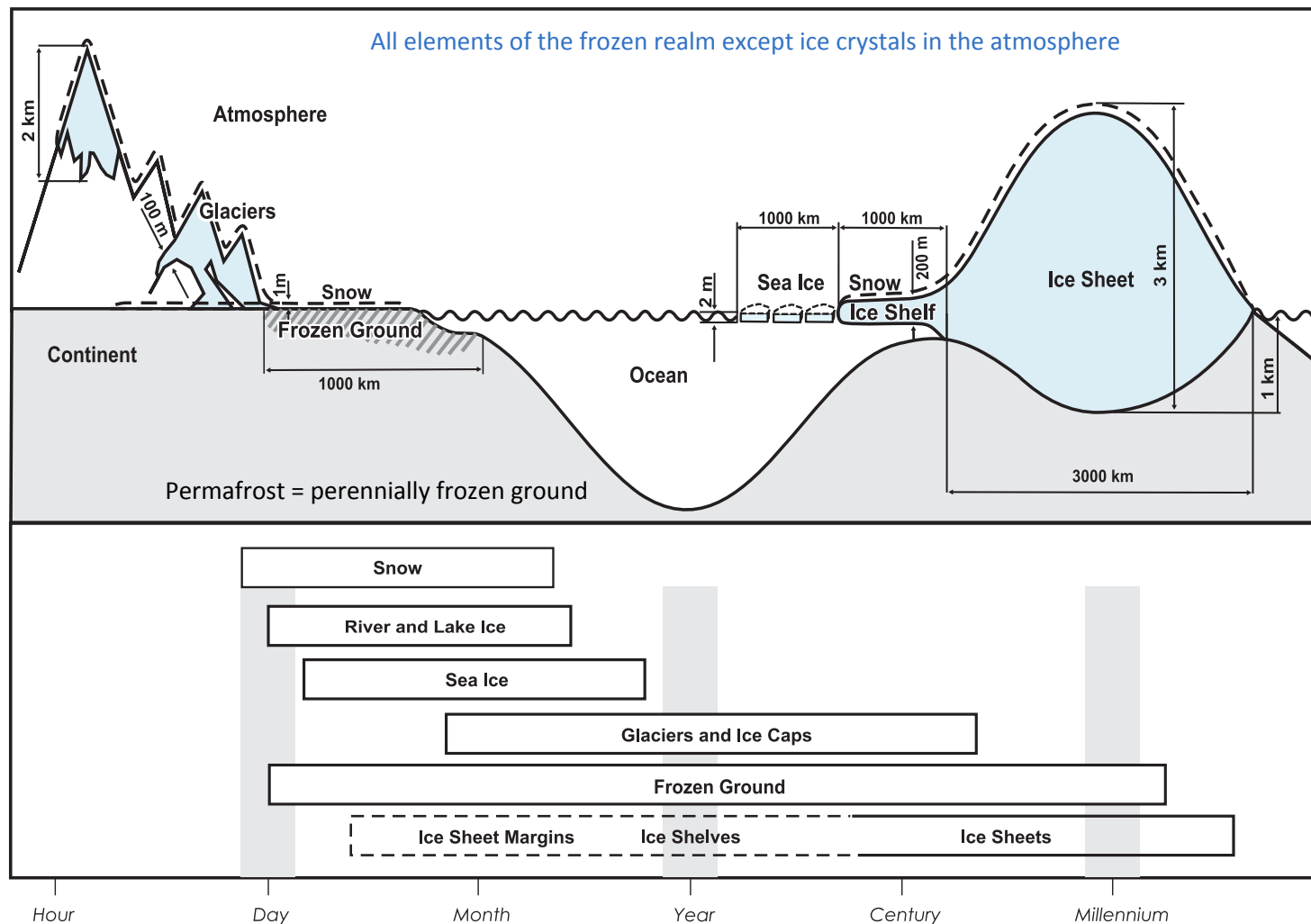
Arctic ocean gains heat in spring-summer and loses in fall-winter



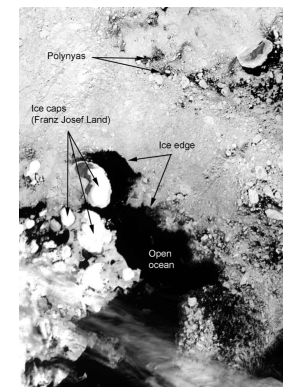
Arctic amplification

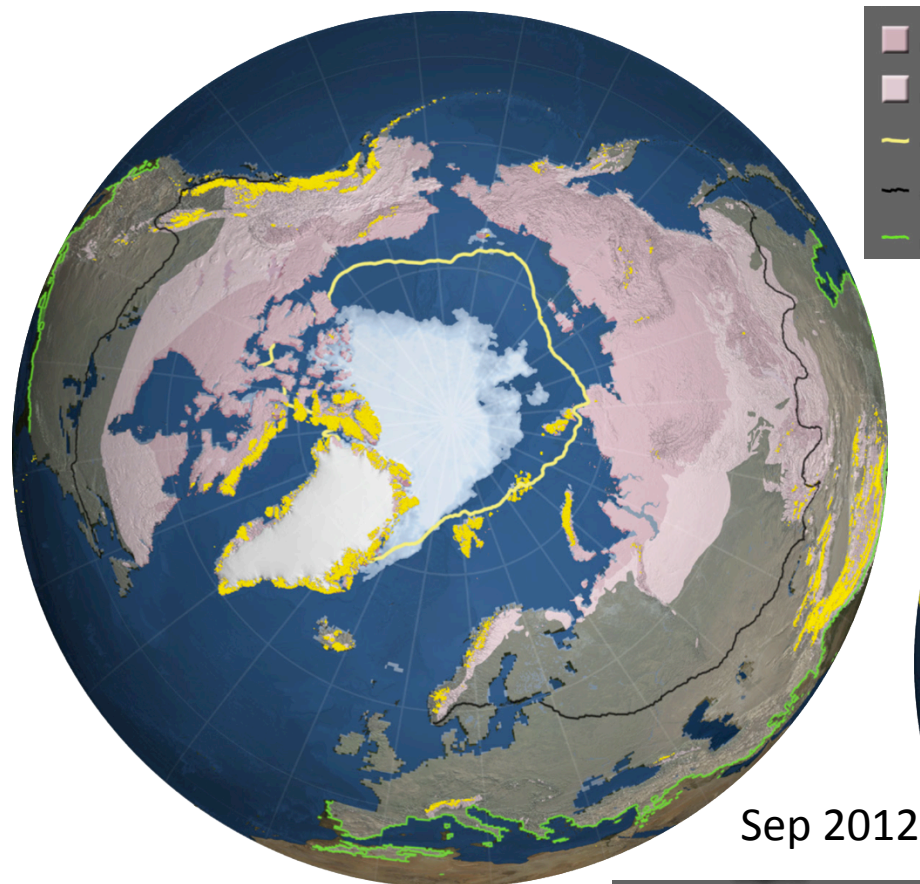


Components of cryosphere and their time scales

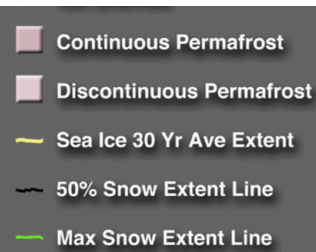
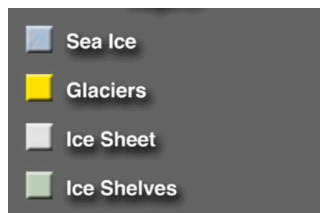


≈35% of surface
(≈50% of land)
experiences
temperature
below the triple
point at some
time in a year

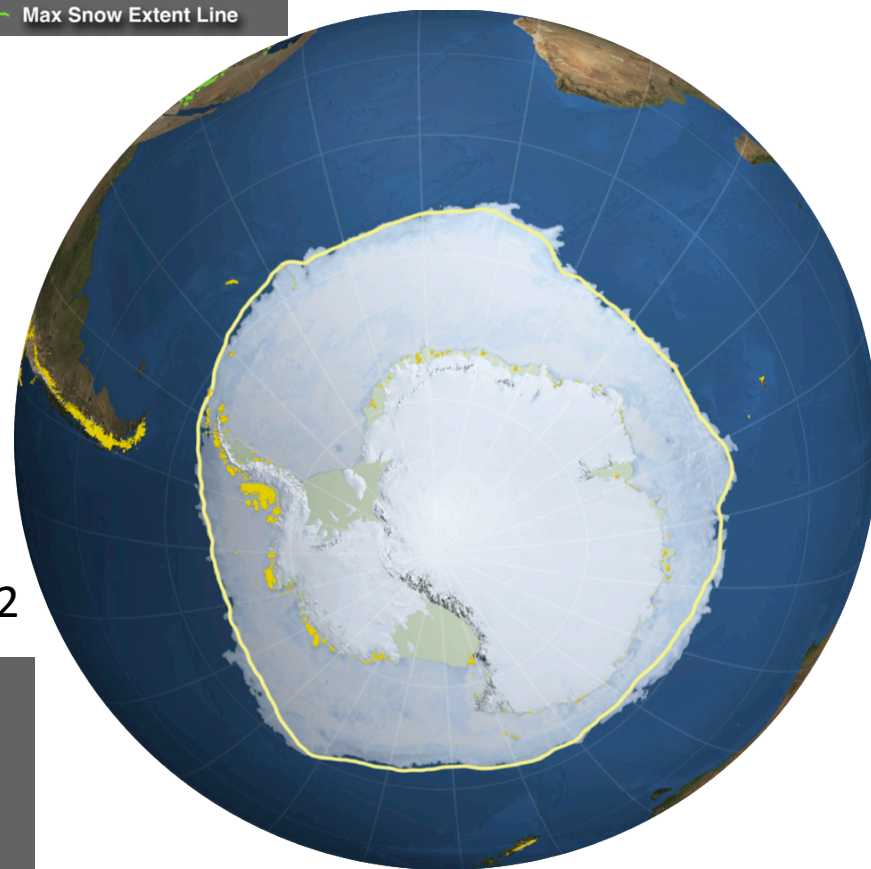




Arctic = ocean
surrounded by land



Antarctic = ice sheet
surrounded by ocean



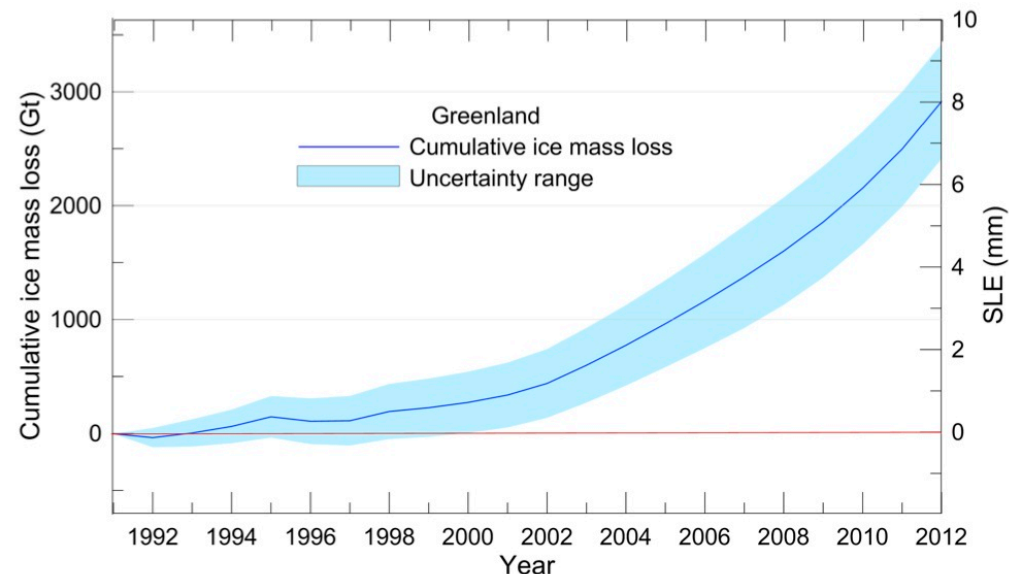
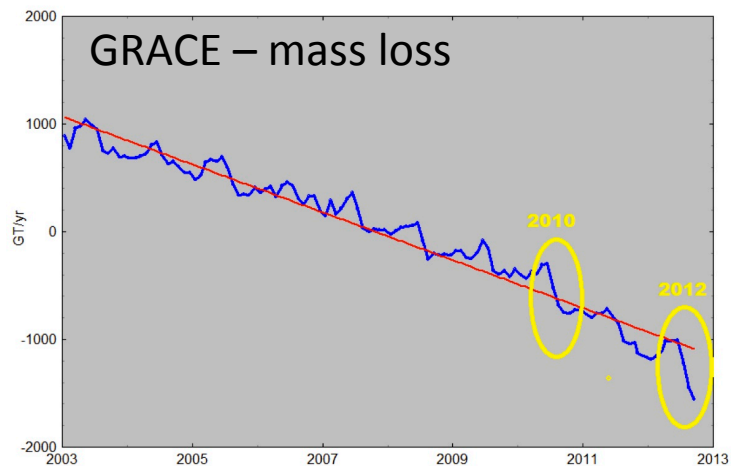
● Greenland ice sheet

Greenland ice sheet has lost mass over the last two decades and loss is accelerating

GRACE yearly mass loss (GT):

.. 2004 ..	2006 ..	2008 ..	2010 ..	2012
148	177	282	419	556

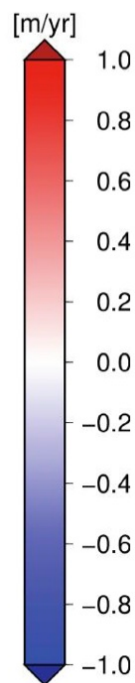
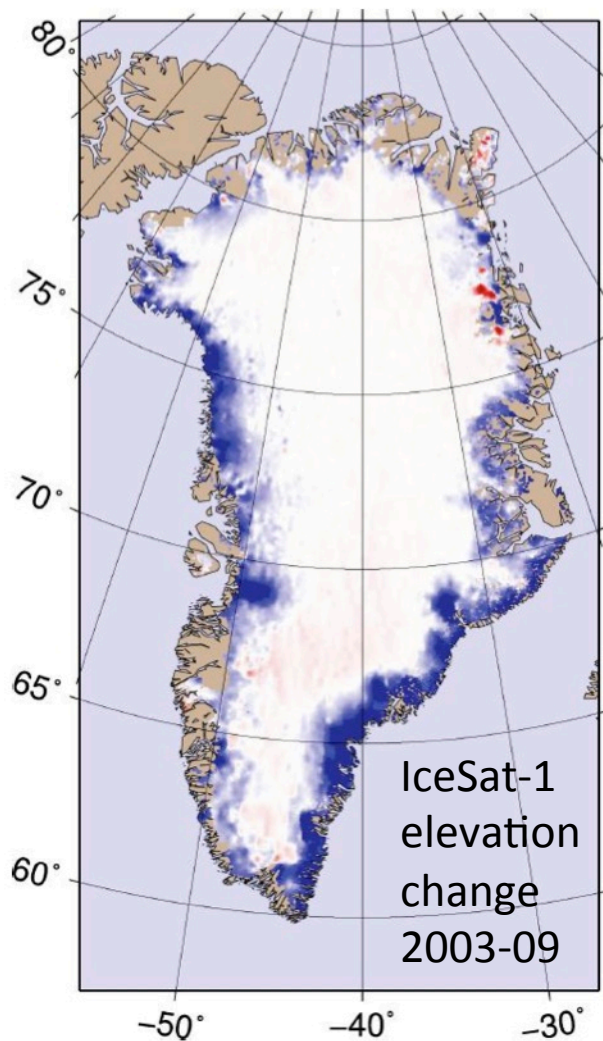
⇒ trend = -244 ± 20 GT/yr



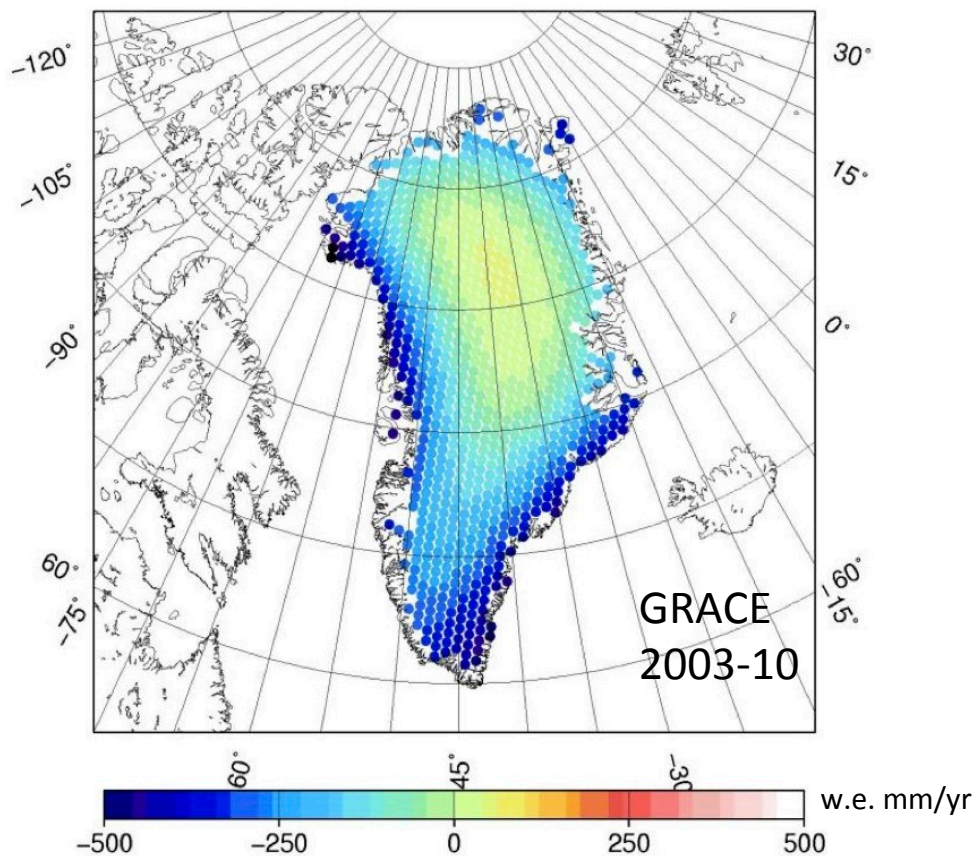
Greenland loss is split in approximately similar amounts between surface melt and outlet glacier discharge, and both parts have increased

Area of summer melt has increased as well over the last two decades





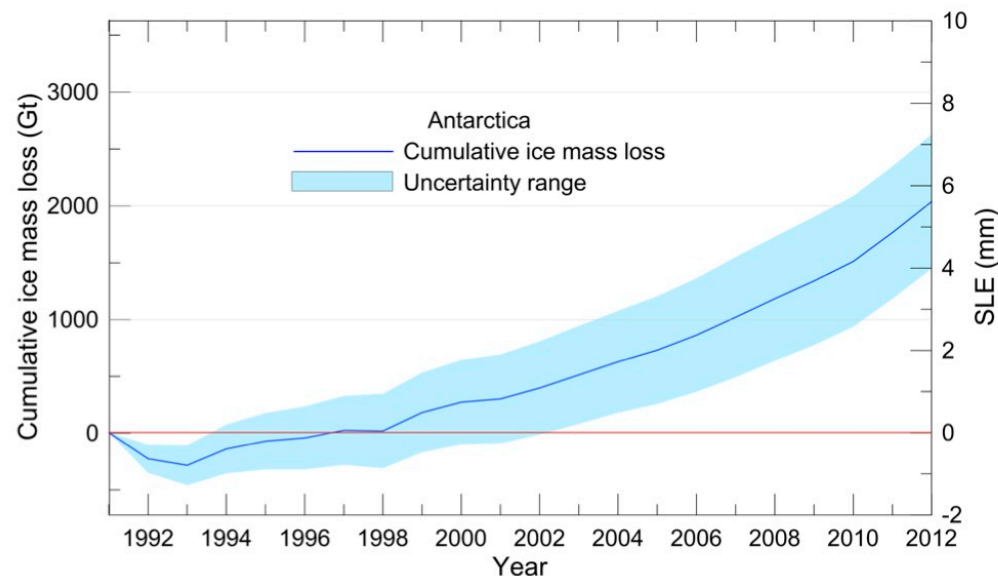
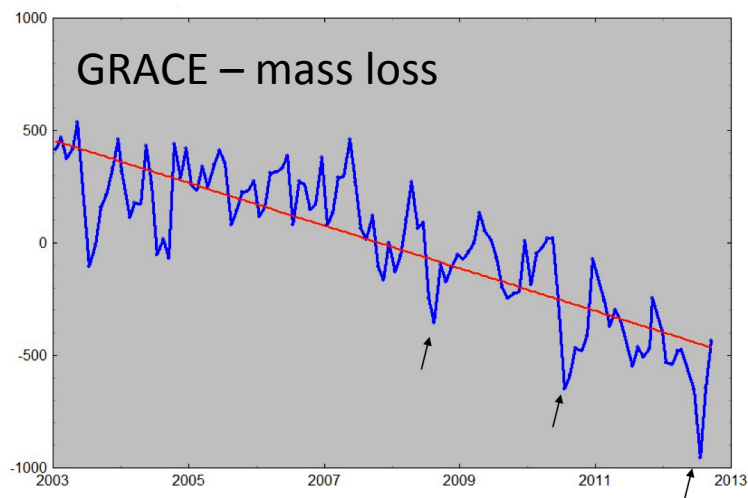
Satellite, airborne and field data indicate that the ice loss has occurred in several sectors



● Antarctic ice sheet

Antarctic ice sheet has lost mass over the last two decades, but there is little difference in total snow fall and no long-term trend in accumulation over the continent

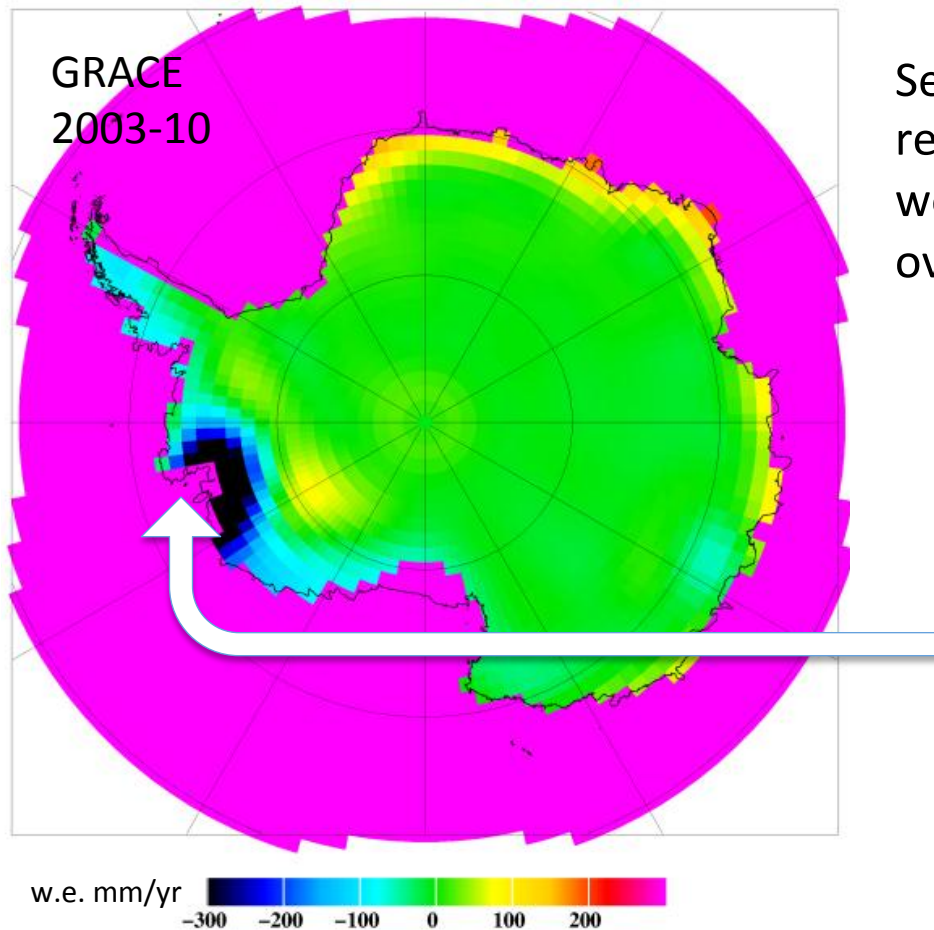
⇒ trend = -95 ± 50 GT/yr



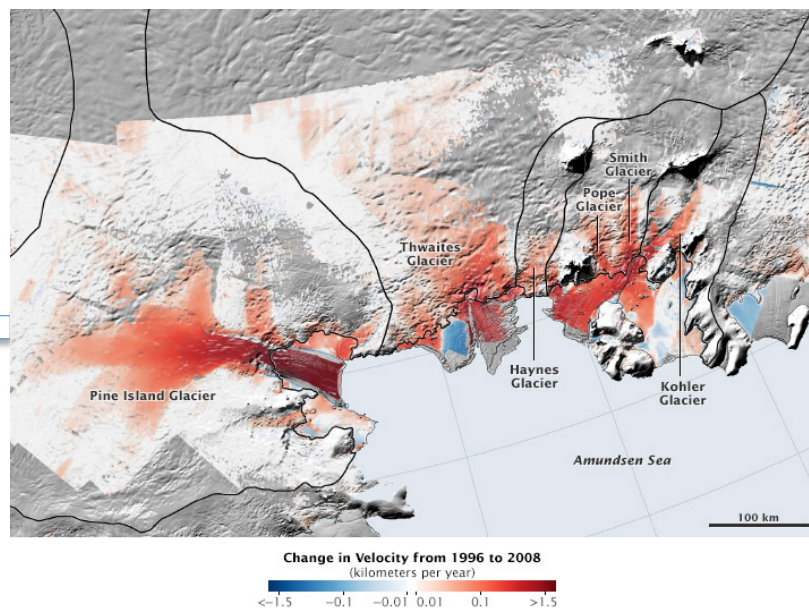
Ice mass changes are concentrated on outlet glaciers and ice streams

Ice shelves round the Antarctic Peninsula continue a long-term trend of retreat and partial collapse that began decades ago related to changing atmospheric temp.

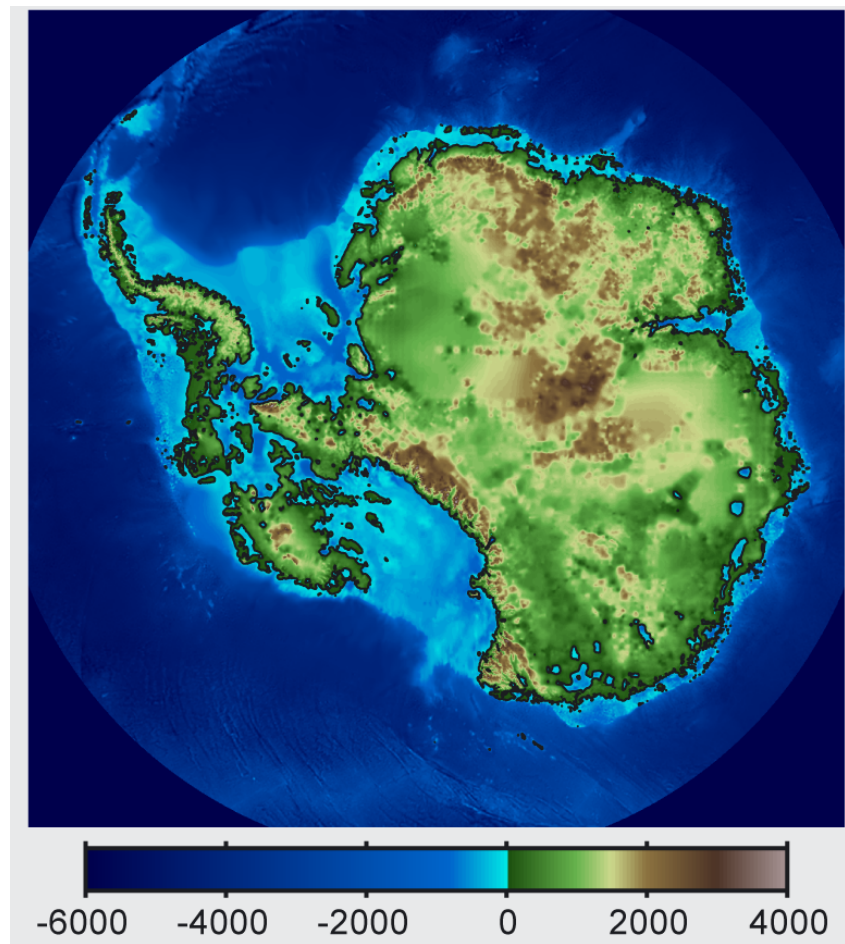
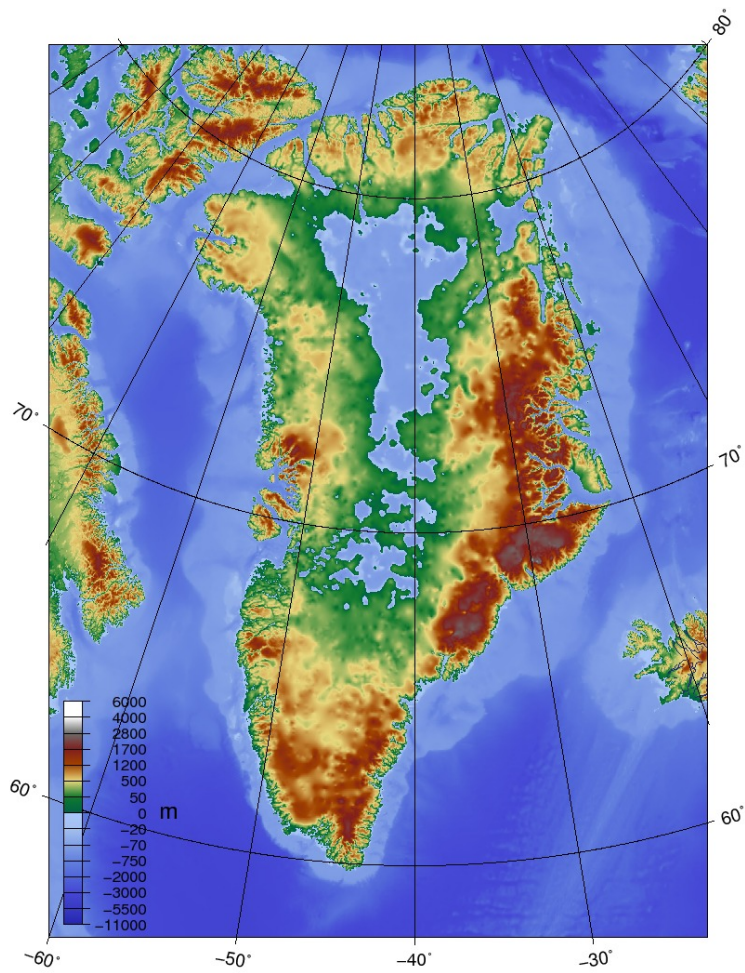
Ice losses are mainly from the northern Antarctic Peninsula and the Amundsen Sea sector of West Antarctica (acceleration of outlet glaciers)



Section of the West Antarctic ice sheet has reached a point of inevitable collapse that would raise sea levels more than a meter over the next few centuries

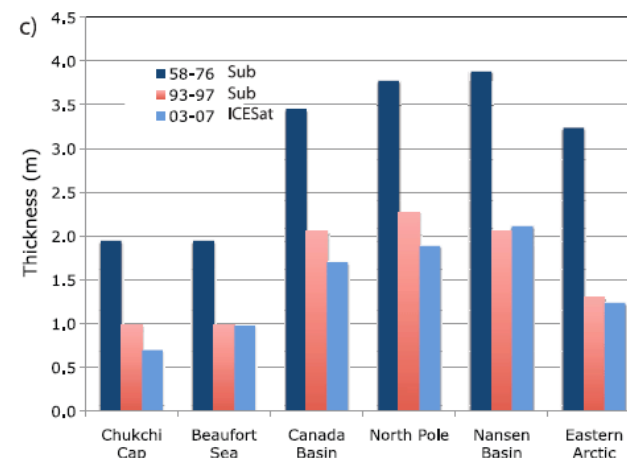
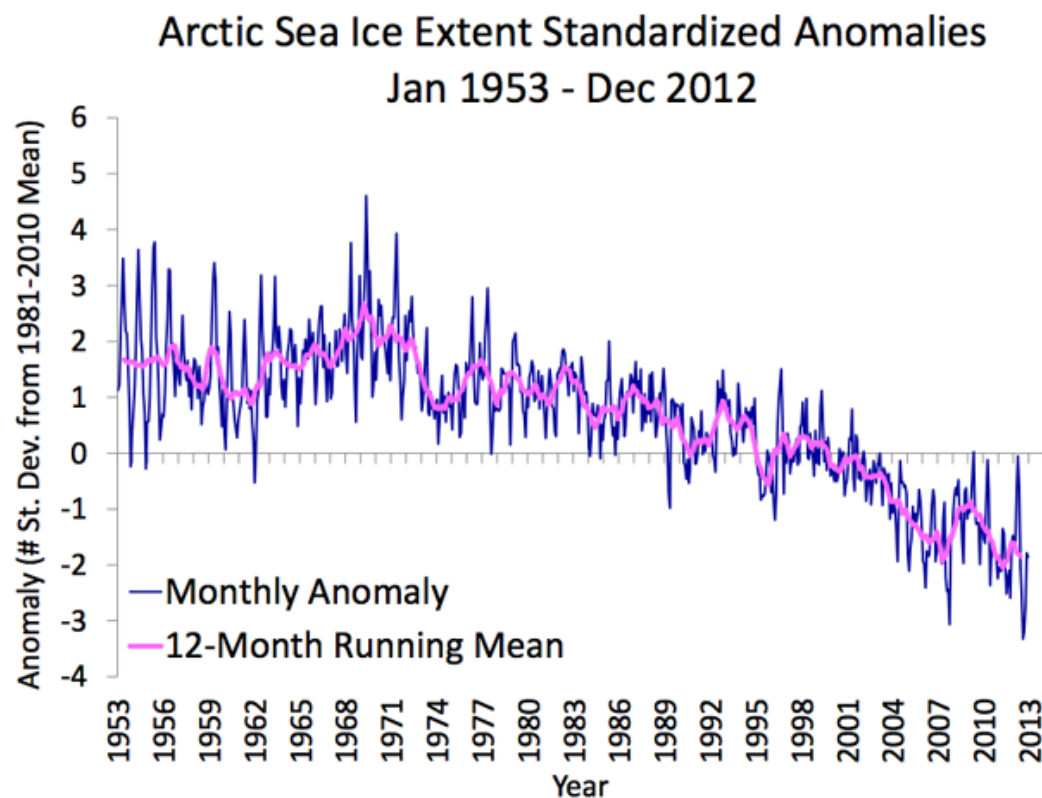


● Topography of Greenland and Antarctic bedrock

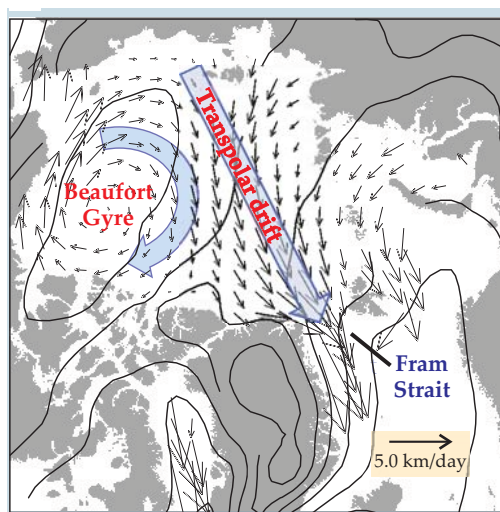


● Arctic sea ice

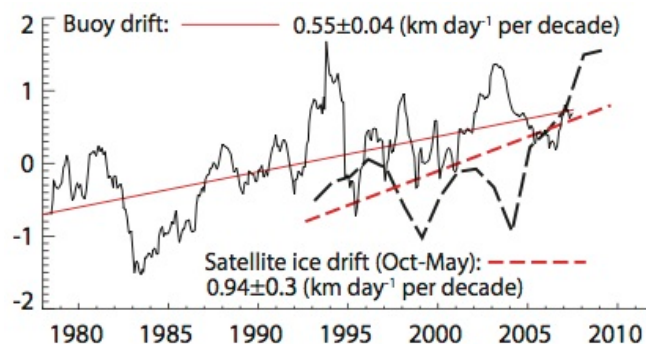
NH sea ice cover has experienced a substantial long-term decline superimposed onto the strong internal variability



Average winter sea ice thickness within the Arctic basin decreased since 1950s



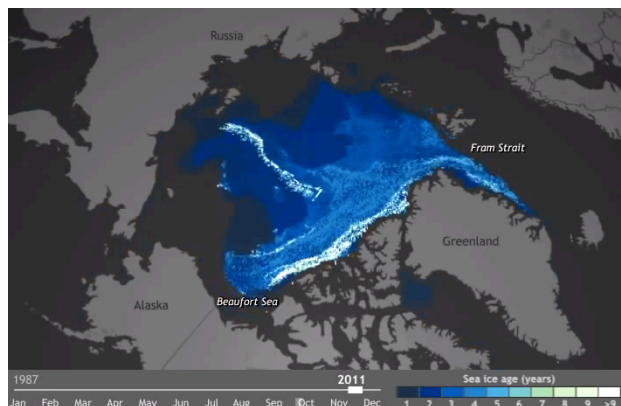
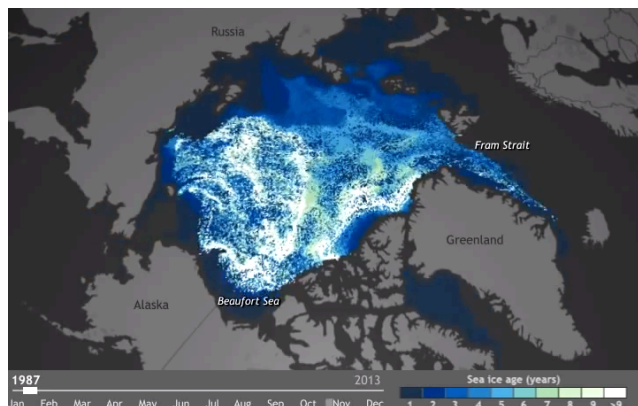
Sea ice speed (extent and age)
has increased (have decreased)



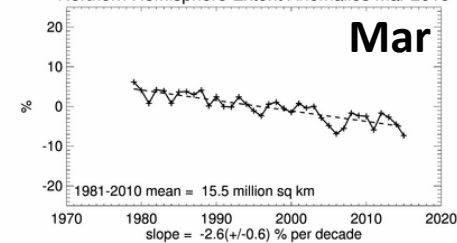
Sea ice age

1987

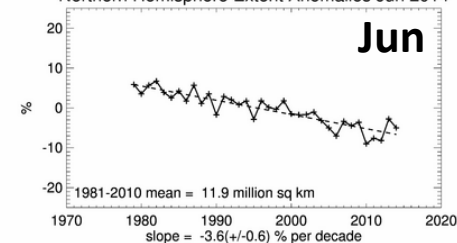
2011



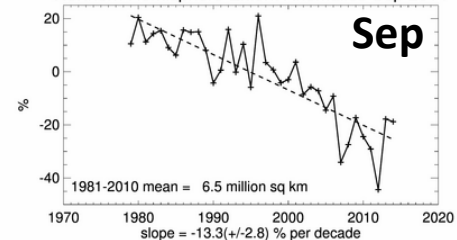
Northern Hemisphere Extent Anomalies Mar 2015



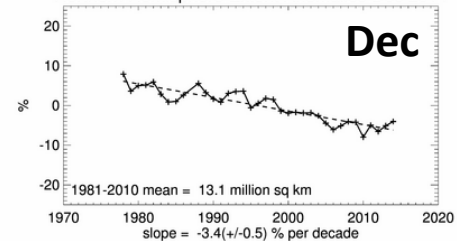
Northern Hemisphere Extent Anomalies Jun 2014



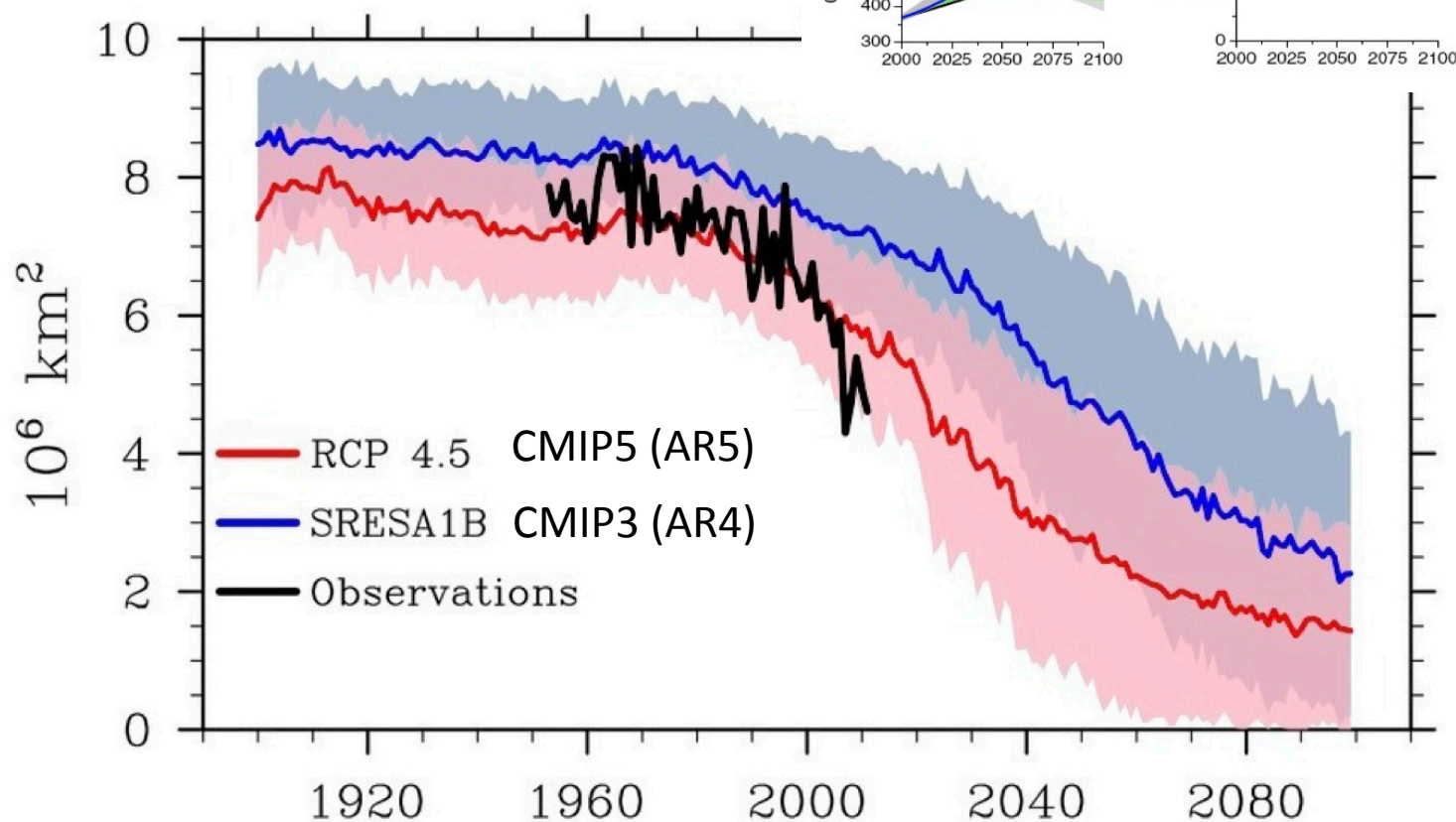
Northern Hemisphere Extent Anomalies Sep 2014



Northern Hemisphere Extent Anomalies Dec 2014



IPCC projections show that
NH sea ice cover should be
almost gone in summer

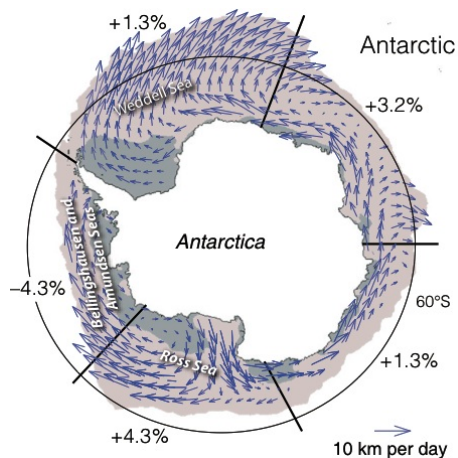


Representative
concentration
pathways (AR5)

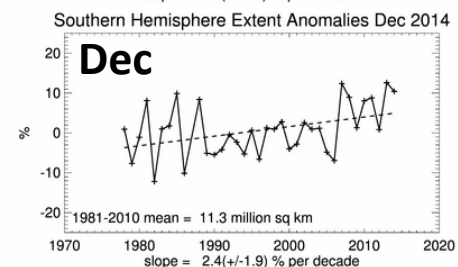
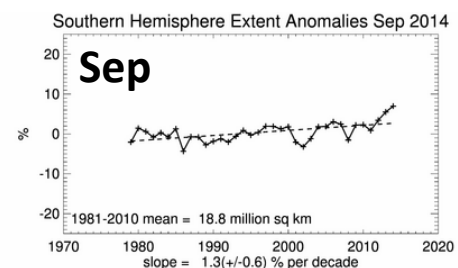
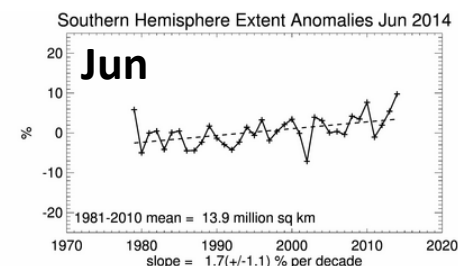
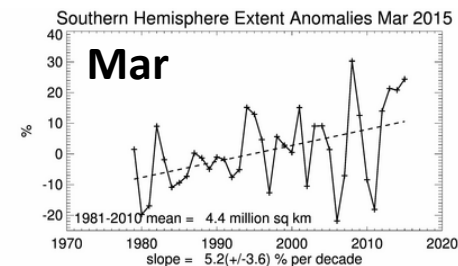
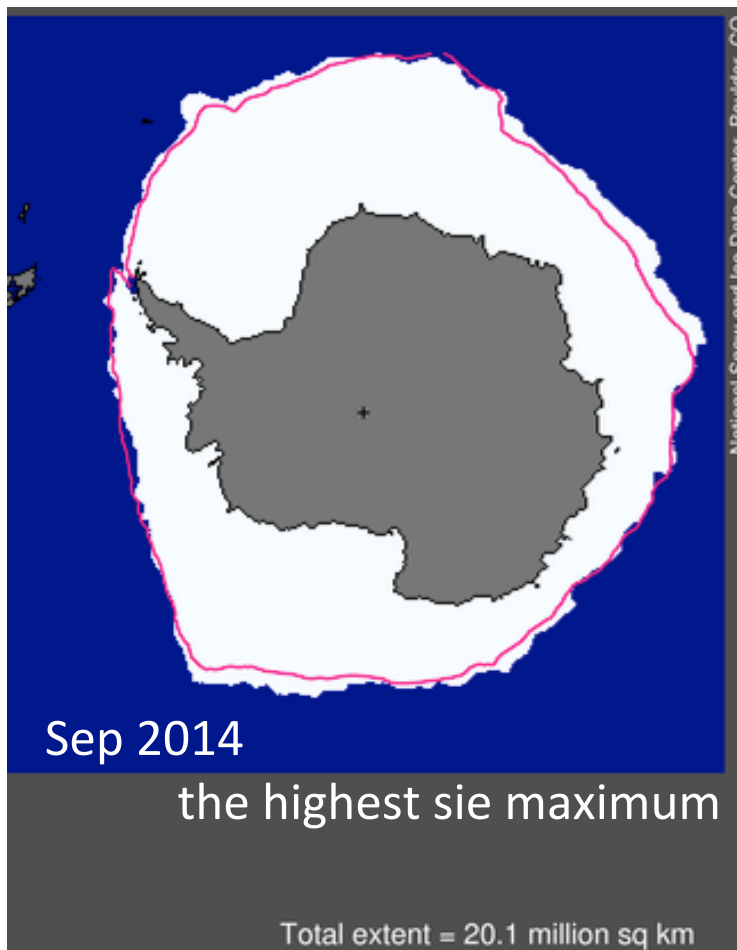
End-of-summer
sea ice extent
is declining at a
faster rate than
expected from
climate model
simulations

• Antarctic sea ice

Annual SH sea ice extent has increased at a rate of between 1.2 and 1.8% /decade



This reflects influence of SAM, ozone hole, ↑GHG and ice shelf melting

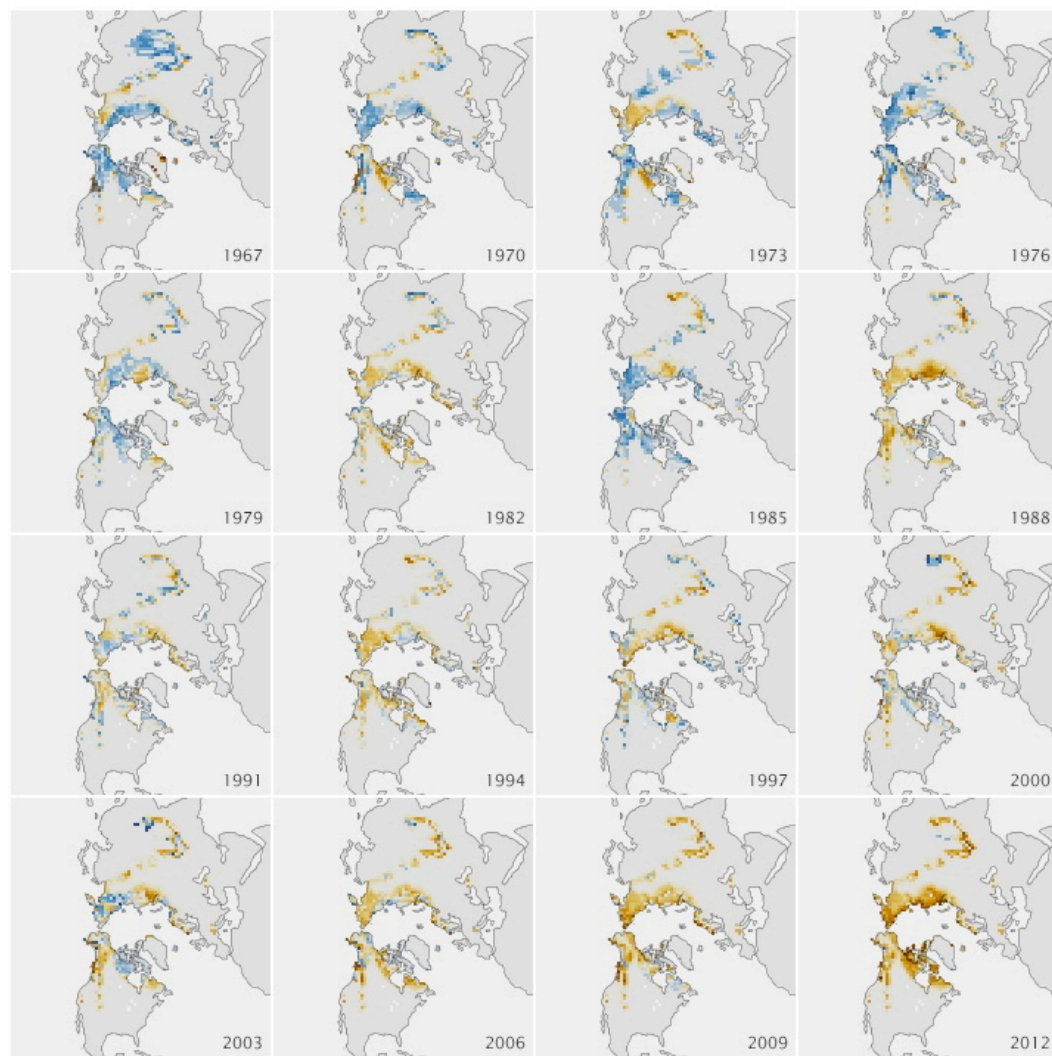
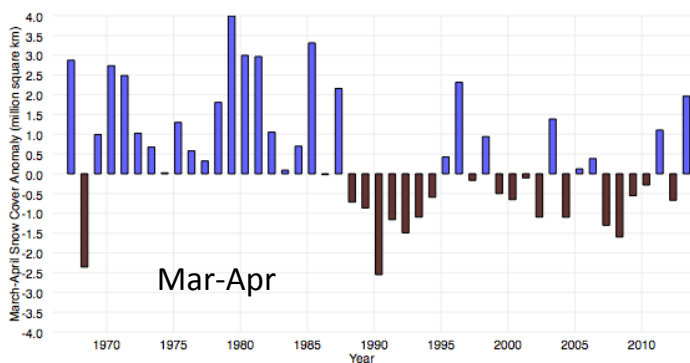


● Snow cover

NH snow cover extent has decreased especially in spring

NH satellite data since 1967 show the largest change in Jun (accelerated since 2003), while Mar and Apr station data since 1922 show similar behavior,

SH data is too limited



(1971-2000)

Most elements of cryosphere has experienced decline, including permafrost, over the observational era and many are projected to do so in the future



Thank you for your attention
Questions?

This boreal pond formed after the permafrost melted in the Alaska Range.

